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POULTRY PROCESSING WASTEWATER TREATMENT AND REUSE

James D. Clise

Maryland Department of Health and Mental Hygiene

Prepared for:

Environmental Protection Agency
Pacific Northwest Environmental Research Laboratory

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16. Abstract

The feasibility of reclaiming poultry processing wastewater for reuse where potable water is presently required was studied at the Sterling Processing Corporation plant in Oakland, Maryland, by the Maryland State Department of Health and Mental Hygiene. In addition, extensive study was made of poultry processing raw waste characteristics and proportions of wastes generated during processing and plant cleanup. Effluent characteristics from a two-stage aerated lagoon are reported.

The reclaiming process consisted of a two-stage aerated lagoon wastewater treatment system followed by an advanced water treatment system of microstraining, flocculation, sedimentation, and sand filtration.

The bacteriological, chemical, and physical drinking water standards of the U.S. Public Health Service were consistently met. Samples were composited at random and examined for human enteric virus organisms. All were found to be negative.

The microstraining, flocculation, sedimentation, and sand filtration system had an annual capital and operating cost of $0.71/1000 liters ($0.27/1000 gallons).

17a. Descriptors

Waste Water Treatment*, Reclaimed Water*, Water Reuse*, Recycling*, Water Purification*, Potable Water*, Food Processing Industry, Poultry, Water Pollution Control, Water Treatment, Flocculation, Filtration.

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Poultry Processing Industry, Aerated Lagoons, Microstraining, Diatomaceous Earth Filter, Sand Filter.

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POULTRY PROCESSING WASTEWATER TREATMENT AND REUSE

By

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Project 12060 FYG
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ABSTRACT

The feasibility of reclaiming poultry processing wastewater for reuse where potable grade water is presently required was studied at the Sterling Processing Corporation plant in Oakland, Maryland, by the Maryland State Department of Health and Mental Hygiene. In addition, extensive study was made of poultry processing raw waste characteristics and proportions of wastes generated during processing and plant cleanup. Effluent characteristics from a two stage aerated lagoon are reported.

Initially, effectiveness of microstraining wastewater lagoon effluent followed by diatomaceous earth filtering was studied. Difficulties were encountered in removal of colloidal solids, eventually identified as protein, which coagulated as the result of low pH values following attempts to chlorinate to breakpoint. Additional facilities were constructed to provide for flocculation and sedimentation prior to filtration. Because of longer filter runs the diatomaceous earth filter was abandoned in favor of sand filtration.

Laboratory studies were conducted to determine compliance of reclaimed water with Public Health Service Drinking Water Standards. Bacteriological, chemical, and physical standards were consistently met with the exception of turbidity resulting from colloidal carryover prior to the addition of flocculation and sedimentation facilities. Even the turbidity standard was met after this addition. The microstraining, flocculation, sedimentation, and sand filtration system had an annual capital and operating cost of $0.27/1,000 gallons ($0.071/1,000 liters).

This report was submitted in fulfillment of Project Number 12060 FYG under partial sponsorship of the Office of Research and Development, Environmental Protection Agency. Work was completed as of July 1973.

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SECTION I

CONCLUSIONS

1. The treatmentof poultry processing wastewater to the level of compliance with biological, chemical, and physical limits in the U.S. Public Health Service (P.H.S.) Drinking Water Standards is feasible from the standpoint of practical application of available equipment and economics.

2. In addition to those problems normally encountered in the treatment of wastewater for reuse, advanced treatment of poultry processing wastewater is further complicated by the presence of colloidal protein. Treatment systems designed to reclaim poultry processing wastewater should include facilities for coagulation and sedimentation for the removal of colloidal solids.

3. Use of breakpoint chlorination to obtain free residual chlorine in the microstrainer effluent prior to diatomaceous earth filtration was impractical. This was due to the high chlorine demand at this stage and the emission of trichloramine fumes from the degradation of organic colloidal material.

4. With the later use of coagulation and sedimentation prior to filtration, the chlorine demand was reduced and "breakpoint" chlorination of the sedimentation basin overflow was reached consistently with standard chlorination equipment.

5. The effect of body feed on the diatomaceous earth filter efficiency increased the average run from 19,840 gallons (75,094 liter) to 29,518 gallons (111,726 liter). With body feed the average flow rate was 194 gpm (12.2 l/sec), but in no instance was the design flow rate of 300 gpm (19.1 l/s) reached.

6. Annual capital and operating expense approximated $0.69/1000 gallons ($0.18/1000 liter) for the originally designed system of microstraining and diatomaceous earth filtration.

7. Following placement of a flocculation and sedimentation unit behind the microstrainer and replacement of diatomaceous earth filtration with sand filtration, the design flow rate of 300 gpm (19.1 l/s) was reached.

8. Annual capital and operating expense for advanced treatment of lagoon effluent approximated $0.27/1000 gallons ($0.071/1000 liter) using the flocculation and sedimentation, and sand filter system in series with the microstrainer.

9. Examination of reclaimed water by the Maryland State Department of Health and Mental Hygiene Virology Laboratory, utilizing the Dr. Joseph L. Melnick (Baylor University) Polyelectrolyte Technique, failed to reveal the presence of any human enteric virus.

10. For average raw wastewater characteristics of 543 mg/l five day BOD, 831 mg/l suspended solids, and 863 mg/l COD; the percent reductions by the two stage aerated lagoon, based on the average effluent characteristics, were 92.8, 85.9, and 89.4 percent, respectively.

11. Correlation between the live weight of birds being processed and wastewater loads was erratic and appeared to be of little or no consequence in the design of wastewater treatment facilities.

SECTION II

RECOMMENDATIONS

The technical and economic feasibility of reclaiming poultry processing wastewater to level of compliance with bacteriological, chemical, and physical criteria of Drinking Water Standards creates the potential for reuse where potable grade water is presently required. Based on established criteria, few, if any, surface sources of raw water could compare with the level of attainable quality demonstrated by this project. It is recommended the project be continued with the following objectives.

1. To demonstrate reliability of the unit to continuously provide the demonstrated level of treatment.
2. To determine uses that can safely be made of reclaimed poultry processing wastewater.
3. To demonstrate the presence or absence of health significant characteristics of reclaimed poultry processing wastewater not demonstrated by application of existing Drinking Water Standards.

SECTION III

INTRODUCTION

Sterling Processing Corporation, a company engaged in the slaughtering, eviscerating, and processing of poultry, is located in Oakland, MD. Plant facilities were constructed in 1956-57, with an original capacity of 3,000 birds an hour, equipped to process broilers, fowl, turkeys, and kosher killed turkeys. Present plant capacity is 6,000 birds an hour with operations restricted to the processing of broilers, averaging 167,000 lbs. (75,750 kg.) live weight killed (lwk) per day.

Wastewater at the Sterling plant results from the processing of poultry which is delivered live, slaughtered, scalded, picked, eviscerated, chilled, cut up, and packaged; from refrigeration drains; and from plant cleanup. The sanitary sewage from the toilets is not mixed with these wastewaters, but disposed of in a separate system.

Production at the Sterling plant has been limited by the availability of potable water, with frequent interruptions to operations resulting from water shortages. A proposal was submitted to the Federal Water Pollution Control Administration, U.S. Department of Interior, in 1970, requesting financial support for a water reclaiming project to investigate the utilization of reclaimed wastewater for plant water supply augmentation. The primary objective of the proposal was to demonstrate the technical and economic feasibility of reclaiming poultry eviscerating wastewater for reuse where potable grade water is presently required. Drinking water for the employees was to be from bottle water fountains. The project was also to provide an opportunity for extensive study of poultry eviscerating wastewater characteristics.

Prior to the beginning of this project, Sterling Processing Corporation initiated a series of water conservation measures. Initially, an employee awareness program was conducted. Written directions were issued and daily inspections were made to identify opportunities for employees to assist in the reduction of wasted water. The entire piping system was inspected and all leaks eliminated. Where possible,

the use of hoses was eliminated and all essential hoses were equipped with automatic shut-off valves. A valve was installed on each supply line serving the processing plant to allow for regulation of flow. A portable high pressure cleaning system was installed and cleanup personnel were provided with brooms to assist in the removal of solids from the floors. Refrigeration compressor water was recycled to the raw water section of the water treatment plant. Pumps were provided to allow the recycling of chill vat water for reuse in the scalder. Valves were provided on the water lines leading to the water treatment plant filters to more closely control filter rates and eliminate water pressure variations within the distribution system. These efforts reduced water consumption from 11 gallons (41.64 liters) per bird to an average of 6.8 gallons (25.74 liters).

The community water supply serving the town of Oakland is of inadequate capacity to provide water to the poultry plant. Groundwater resources in the area are limited and of unsatisfactory quality. Sterling Processing Corporation constructed two wells in 1956, and has since acquired a third well which was abandoned by Oakland when the town obtained a surface water supply. In 1965, a water treatment facility was constructed at the poultry plant and is currently in use for the removal of iron and control of bacteriological quality.

Treatment consists of alum-lime flocculation, with final pH adjustment for iron precipitation, followed by settling and filtration. Raw water is prechlorinated in the mixing basin, with additional chlorine for residual control introduced into the main service line leading to the processing plant. Settled water is filtered through two sand filters, each 15 feet (4.57 m) in diameter, operated alternately at a maximum rate of 350 gpm (22.1 l/s). Filter outlet pressure fluctuation due to variation in filter condition results in erratic flow rates through water outlets on poultry processing lines. Significant water conservation has been attained through controlled application rates onto the filters.

Poultry processing wastes are treated and disposed of by rotary

screening for removal of feathers and viscera which are sold for protein reclamation, with wastewater treated in two mechanically aerated lagoons in series, followed by chlorination and discharge to the Little Youghiogheny River. Present wastewater treatment facilities were constructed in 1965-66, replacing an anaerobic lagoon which discharged into the Oakland sewer system.

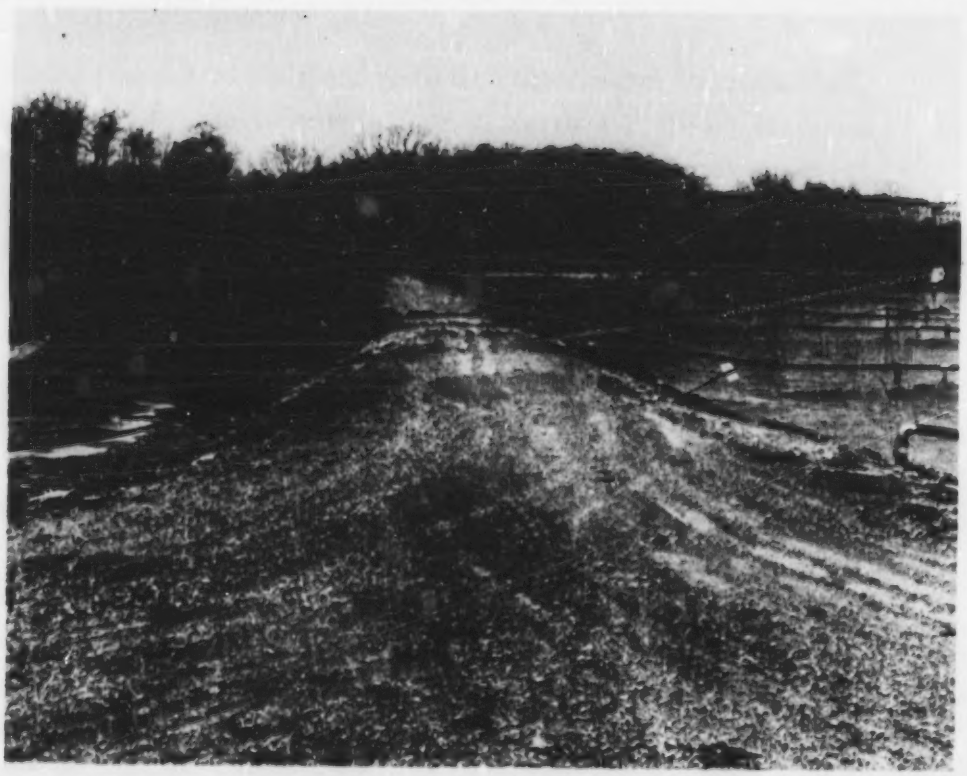


Figure 1

Sterling Wastewater Lagoon System

The wastewater treatment system consists of two lagoons totalling 2.75 acres (1.11 hectares) in area. Each lagoon is 140' (42.7 m) wide. The primary unit is 590' (177 m) long and the secondary lagoon is 230' (69) long. Each pond is six feet (1.8 m) deep. Primary lagoon capacity is approximately 3.75 million gallons (14,195 m^3) and secondary capacity is 1.5 million gallons (5,678 m^3) providing holding capacity for 12 working days' flow.

The primary lagoon is equipped with 64 Link Belt circulators, a grease skimmer, and an effluent wier trough discharging into the second lagoon, (Figure 1).

Figure 2

Primary Lagoon, Showing Surface
Turbulence From Circulator Discharge

Entering at the bottom of the circulators, wastewater is discharged at the surface in one direction, creating a counter-clockwise surface flow, (Figure 2).

Air is supplied to the circulators by three positive displacement blowers, each powered by a 20 hp (14.9 kw) motor. The system provides 3,360 cfm (15.8 m^3/s) of air at 2.8 psig (19.3 kN/m^2). Air is distributed to the circulators through a header pipe encircling the two lagoons.

The secondary lagoon is equipped with 40 Ling Belt circulators, a grease skimmer, and a combination settling unit and chlorine contact chamber with an overflow wier trough and discharge line to the river, (Figure 3).

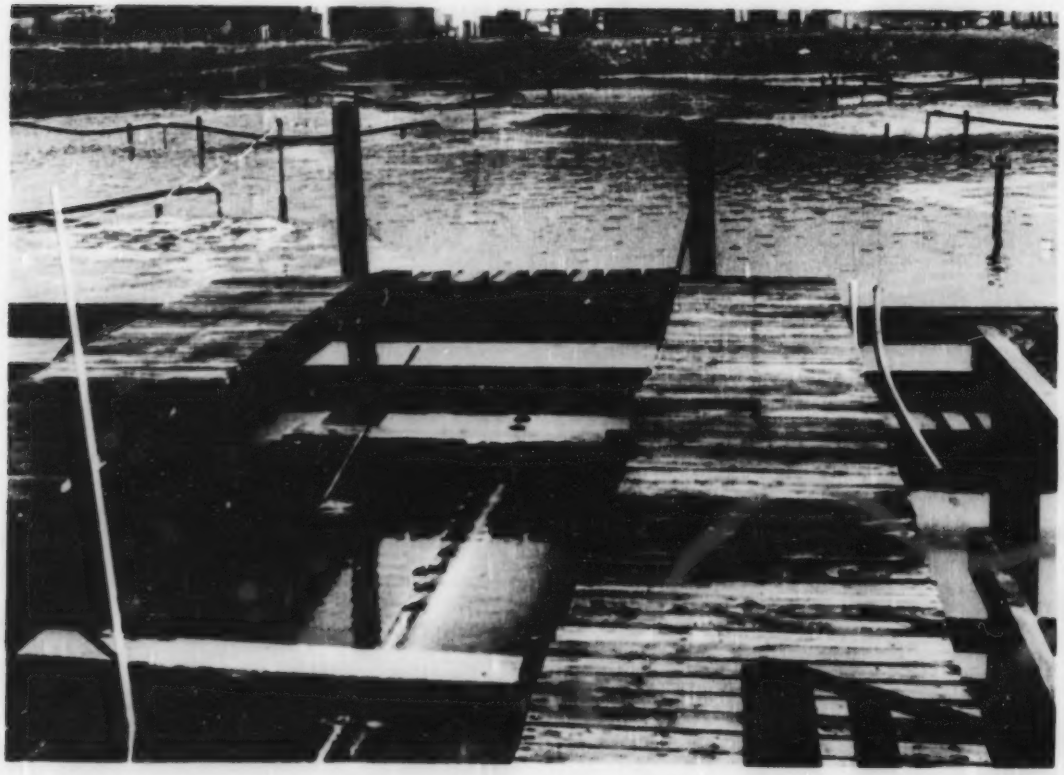


Figure 3

Final Settling Basin, Chlorine Contact Chamber and Overflow Wier Discharging to River

Incoming raw wastewater has a BOD_5 averaging 450 mg/l, amounting to a loading approximating 400 lbs/acre/day (448 kg/ha/day) with a 93% reduction in the lagoon system. Raw wastewater suspended solids average 858 mg/l equating a loading of 750 lbs/acre/day (841 kg/ha/day) with an 88% reduction in the system.

Wastewater treatment facilities were designed and installed by Griffith Engineering of Falls Church, Virginia.

The project as approved by the Department of Interior in January, 1971, was for a two-year period under project number 12060 FYG, later extended to July, 1973. Federal funds supported the construction of an advanced water treatment plant to reclaim wastewater effluent for use in augmenting Sterling's limited potable water supply and provided for operation and continuous surveillance of the units. Expansion of Department of Health laboratory capabilities was necessary for daily monitoring of the units.

The project was designed in three phases. The first phase was for design and construction of the advanced water treatment facility. Phase two was for operation and study of effectiveness of the water treatment facility, and phase three was for introduction of reclaimed water into the poultry plant's cleanup procedures with ultimate integration of reclaimed water into the plant's raw water supply.

A preliminary study of the wastewater effluent indicated that reclaiming facilities should provide for removal of suspended solids; chlorination, preferable to breakpoint; and final filtration. The facility was designed with these needs in mind.

SECTION IV

WASTEWATER CHARACTERISTICS

The project provided an opportunity for extensive study of poultry wastewater characteristics. Studies included daily continuous sampling of raw wastes, and segregated sampling of processing and cleanup wastes.

Composite samplers were installed on the wastewater line from the poultry plant to the primary wastewater lagoon, with samples collected each morning prior to beginning of plant operations. Composite samplers provided for continuous contribution to samples from the normal eight hours of operation, and six to eight hours of plant cleanup.

Table 1 shows average values of wastewater characteristics studied. It should be noted that throughout the study total water usage averaged 6.8 gallons (25.741iters) per bird.

Table 1. RAW WASTEWATER CHARACTERISTICS
Station A - mg/l

	Number of Samples	Mean Value	Standard Deviation	Maximum Value	Minimum Value
BOD_5	148	543	229	1043	141
COD	7	863	183	1230	665
Suspended Solids	119	831	464	2780	172
Grease	47	403	239	4667	88

Samples to segregate processing and plant cleanup wastes were collected at the end of each day's operation and again each morning for a period of six weeks.

Volume of water used for plant cleanup consistently approximated the

volume used for processing operations. For the entire six week period studied, the difference between processing and cleanup flows equalled only 6% of the total flow. Total flows average 6.8 gallons (24.74 liters) per bird.

Tables 2 and 3 show percentages and volumes of major wastewater components resulting from processing operations and plant cleanup.

Table 2. PROPORTIONS OF WASTES GENERATED DURING PROCESSING AND CLEANUP

Percent of Total Based on Median Values

	Processing	Cleanup
Water	53	47
BOD_5	87	13
Grease	90	10
Total Solids	78	22
Suspended Solids	85	15
Dissolved Solids	66	34

Table 3. WASTES GENERATED DURING PROCESSING AND CLEANUP

Kg/1000 kg LWK

Mean

	Processing	Cleanup	Total
Water	7,759	6,721	14,300
(Gallons)	(909)	(805)	(1,714)
(Liters)	(3,341)	(3,047)	(6,487)
BOD_5	5.6	0.9	6.5
Grease	9.5	1.0	10.5
Total Solids	18.7	5.3	24.0
Suspended Solids	10.4	1.9	12.5
Dissolved Solids	7.7	4.0	11.7

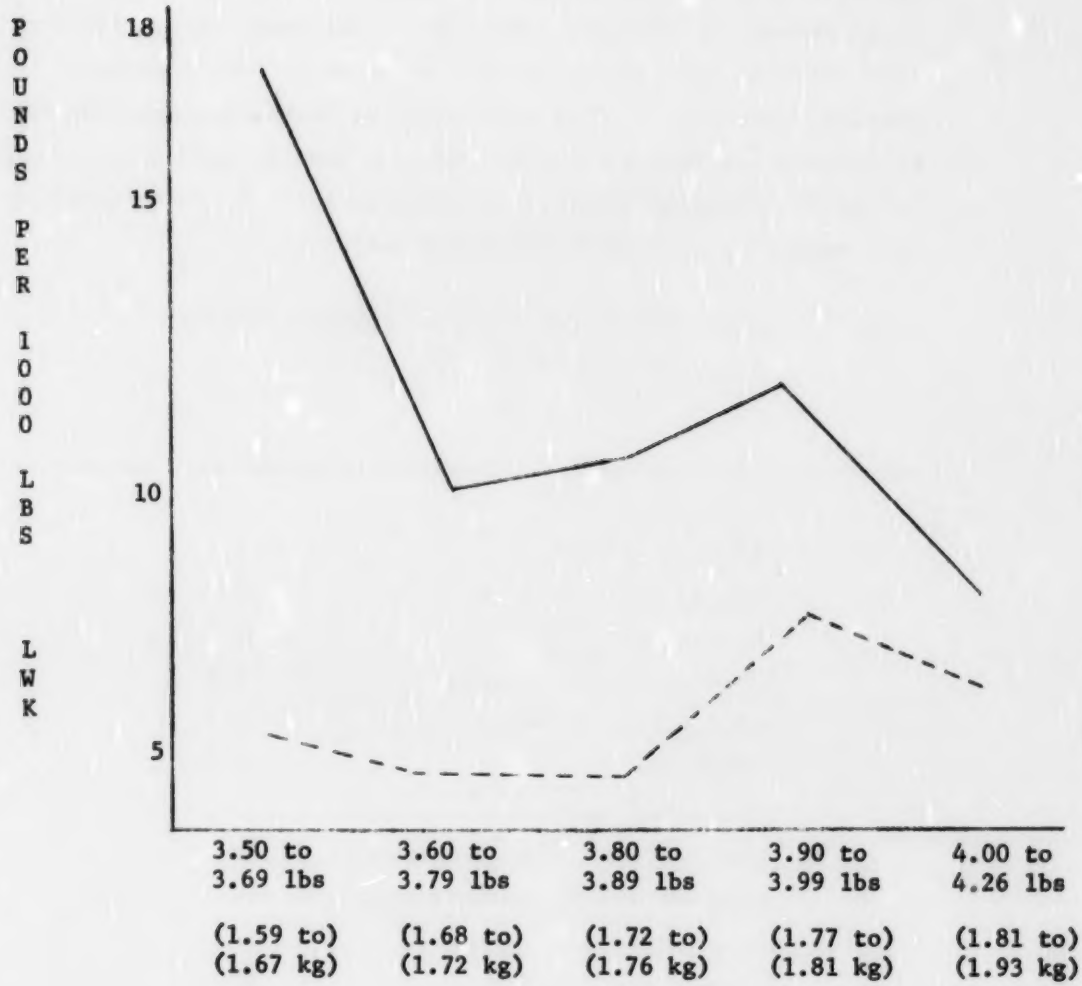
An effort was made to determine if increase in the live weight of birds being processed resulted in variation of wastewater loads. Average daily live weights were compared with daily wastewater composite sample results for a period of eighteen months. Five live weight ranges were selected between 3.5 lbs and 4.26 lbs (1.59 - 1.93 kg). Although distinct variations in wastewater loads can be correlated with average live weight variation, as indicated in Table 4 and Figure 4, Correlations are erratic and would appear to be of little or no consequence in the design of wastewater treatment facilities.

Table 4. BOD_5 AND SUSPENDED SOLIDS COMPARED TO LIVE WEIGHT OF BROILERS

Broiler Live Weight kg (lbs.)	Suspended Solids kg/1000 kg LWK	BOD_5 kg/1000 kg LWK
1.59 - 1.67 (3.5 - 3.69)	16.93	5.64
1.68 - 1.72 (3.7 - 3.79)	9.78	5.18
1.72 - 1.76 (3.8 - 3.89)	10.26	5.26
1.77 - 1.81 (3.9 - 3.99)	11.79	7.58
1.81 - 1.93 (4.0 - 4.26)	8.20	6.80

Figure 4

BOD_5 and Suspended Solids Produced
Per 1000 Lbs. LWK Vs. Weight of Broilers


POUNDS PER 1000 LBS LWK
18
15
10
5
3.50 to 3.69 lbs (1.59 to 1.67 kg)
3.60 to 3.79 lbs (1.68 to 1.72 kg)
3.80 to 3.89 lbs (1.72 to 1.76 kg)
3.90 to 3.99 lbs (1.77 to 1.81 kg)
4.00 to 4.26 lbs (1.81 to 1.93 kg)
Live Weight of Broilers
SS
BOD_5

SECTION V

DESIGN

Preliminary grab sample evaluations of wastewater lagoon effluent indicated the wastewater treatment facility reduced the BOD value to an average of 15 mg/1, (Table 5). Continuous study indicates this value to approximate 30 mg/1 based on 24 hour composite samples, (Table 6). Composite sampling revealed comparable variations in other measurable parameters when compared to grab sample results. The effluent characteristics as shown in Table 5, determined by grab sampling, were used for design purposes.

Table 5. WASTEWATER LAGOON EFFLUENT CHARACTERISTICS USED AS BASIS FOR DESIGN

mg/1

Grease	7.8
Phosphate as P	1.3
Iron as Fe	0.3
Chloride as Cl	88
Nitrogen as Free Ammonia	8.8
Albuminoid Ammonia	1.0
Nitrites	0.005
Nitrates	3.0
Alkalinity as Calcium Carbonate	148
Hardness as Calcium Carbonate	178
Turbidity	30
Color	80
BOD_5	15
Chemical Oxygen Demand (COD)	140
Total Solids	426
Dissolved Oxygen	2.9
Suspended Solids	58
Volatile Solids	400
pH	7.0

Wastewater lagoon effluent characteristics, as determined during the study, exceeded the basic design criterion from 52% to 77% as shown in Table 6, resulting in overloading of equipment and the subsequent alteration of project design.

Table 6. WASTEWATER LAGOON EFFLUENT QUALITY VARIATION FROM VALUES USED FOR DESIGN OF ADVANCED TREATMENT UNIT

	Design Value mg/l	12 Month Mean mg/l	12 Month Median mg/l	Percent Samples Exceeding Design Value
BOD_5	14.8	31	25	52.3%
Suspended Solids	58	106	109	70.0%
Grease	7.8	24	19	76.7%

Basic design of the water treatment facility consists of a control building, (Figure 5); 35 micron microstrainer, (Figure 6); diatomite filter containing 200 square feet (18.6 m^2) of septum, (Figure 7) rated at 1.6 gpm/sq ft (1.08 $l/s/m^2$); and 20,000 gallon (76 m^3) pressure storage tank.

Supplemental equipment consists of a 3,000 gallon (11,360 liter) concrete pit used as a collection sump for lagoon effluent; sewage pump for the delivery of effluent to the microstrainer; high head pump for delivery of microstrained effluent to the diatomite filter (50 psi, 345 kN/m^2); chlorine recorder; and electrical control panel. All equipment is automatically controlled by the water height in the pressure storage tank. Each unit can be independently operated manually. All equipment is rated at approximately 300 gpm (19 liter/s).

Equipment is housed in a 20' x 30'(6.1 m x 9.14 m) concrete block structure located between the poultry plant and wastewater treatment lagoons, (Figure 5).

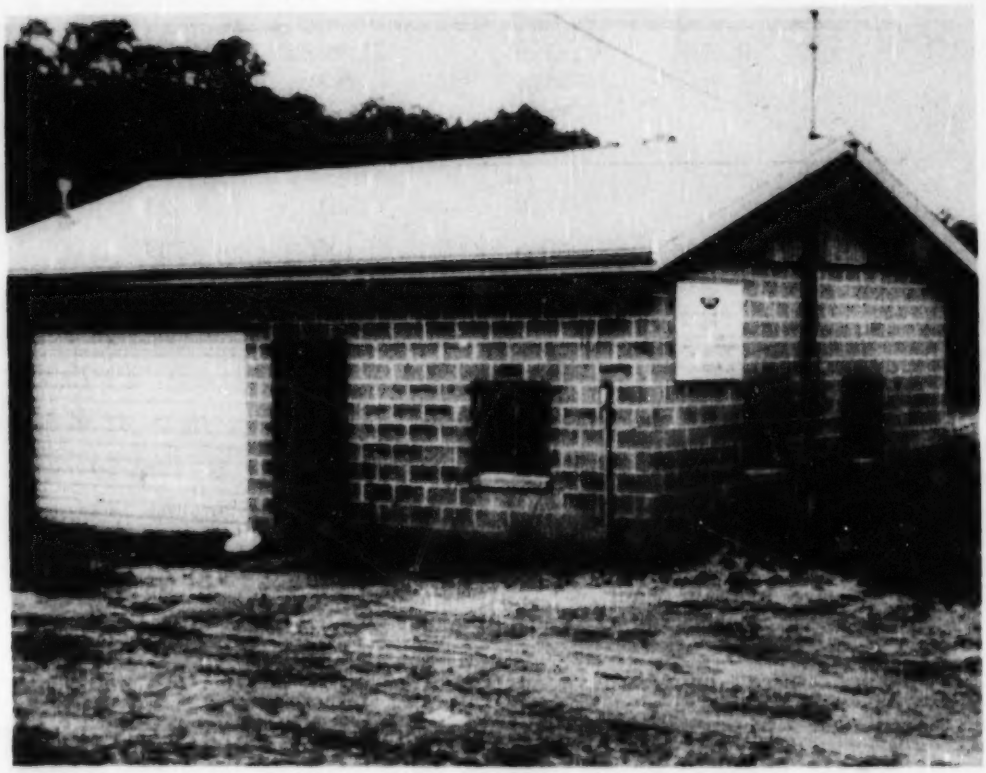


Figure 5
Advanced Water Treatment Control House

Six inch (15.24 cm) PVC pipe is used to carry effluent from the secondary wastewater treatment lagoon overflow sump to the control house. All piping within the control house is 6" (15.24 cm) steel with bolted flange connections.

Solids removed by microstraining of the wastewater lagoon effluent are returned to the primary wastewater lagoon by gravity flow from the microstrainer drum.

Initial design provided for diatomite filter recirculation water to be discharged into the microstrainer sump for return to the filter during recharge, (Figure 6).

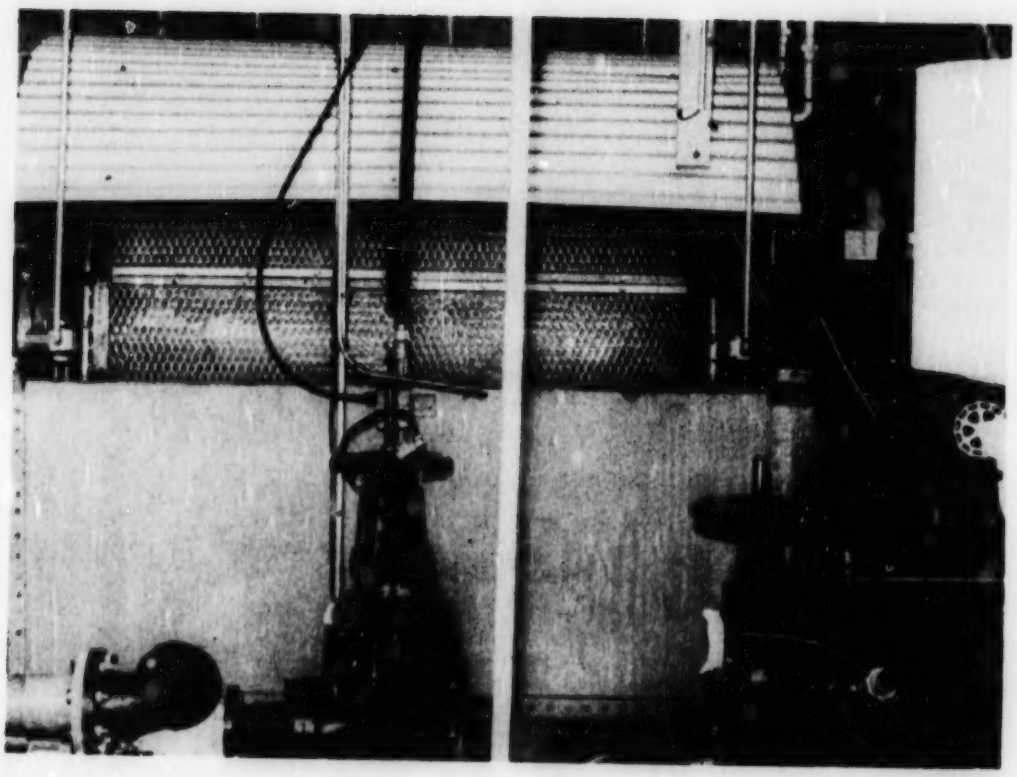


Figure 6
Microstrainer Showing Recirculation Line
From Diatomaceous Filter to Microstrainer Sump

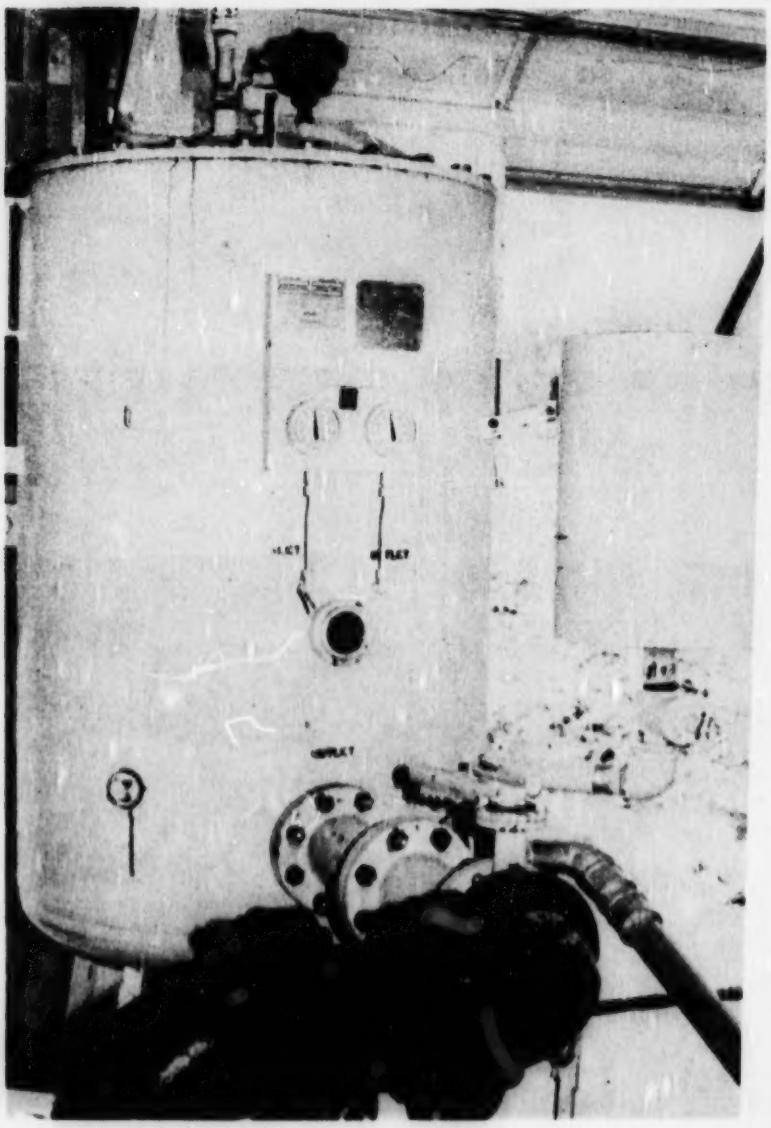


Figure 7

Diatomaceous Filter - 325 gpm (20.5 liter/s) Capacity,
Used in First Phase of Project Operation
To Filter Microstrainer Effluent. This
Unit Was Replaced by Sand Filtration in
Second Phase of Operation

An elevated settling tank was later provided to receive diatomite filter backwash water allowing settled sludge to be withdrawn by gravity and supernatant returned to the primary lagoon.

The pressure storage tank was placed underground, with one end extending through the building wall into a floor sump.

Figure 8 is a schematic outline of wastewater treatment and advanced water treatment flow as originally designed. Indicated sampling points were used throughout the study. Sampling point C was varied to allow sampling of wastewater lagoon effluent before and following chlorination.

WASTEWATER TREATMENT AND WATER RECLAIMING FACILITIES

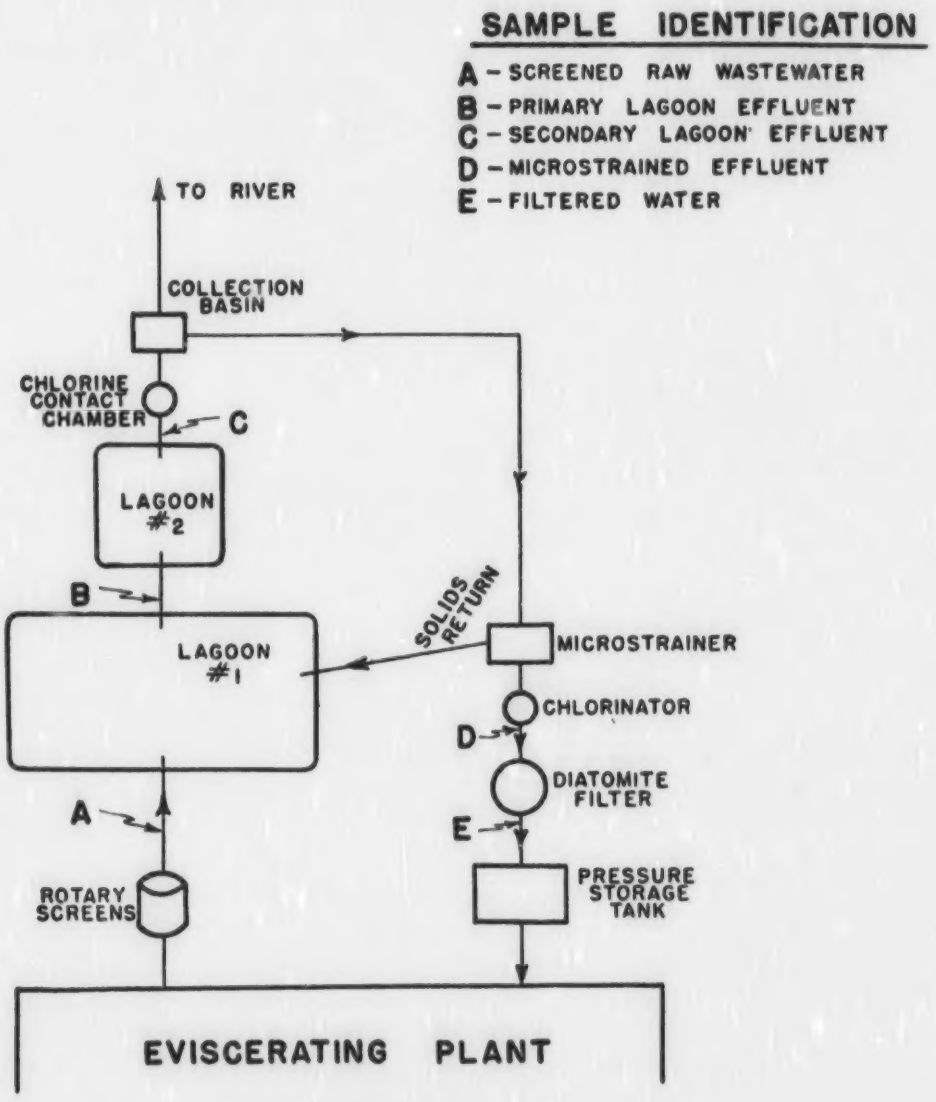


Figure 8

Original Design

Wastewater effluent characteristics as determined during the study varied significantly from those values used in the original design of project facilities, (Table 6).

Variations prompted redesign of the unit to include facilities for flocculation and settling of effluent prior to filtering, and abandonment of the diatomite filter in favor of use of one of the sand filters serving the processing plant's water treatment unit.

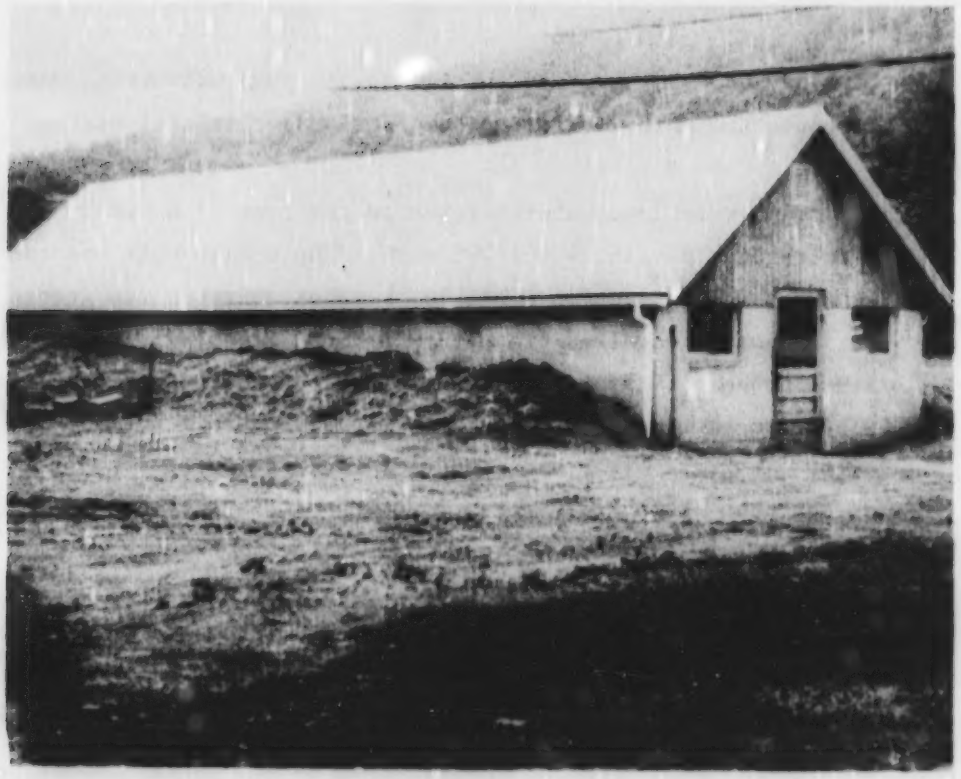


Figure 9
Flocculation - Sedimentation Basin and Flash Mix Room

A flocculation-sedimentation basin was constructed adjacent to the control house. The unit was poured in place with a concrete block lime storage and flash mix room attached, (Figure 9). Overall dimensions are 53' x 16' 4" (16.3 m x 5.7 m), providing for a three minute flash mix following addition of lime, a fifteen minute flocculation chamber, and a settling area of 450 sq ft (42 m^2). The settling basin is 10' 3.05 m) deep, providing for two hours' retention and a maximum overflow rate of 950 gpd/sq ft/day (38.75 m^3/m^2/day).

The floor of the settling basin slopes to a sump at the inlet end to facilitate collection and removal of sludge. Sludge is delivered to ground level utilizing the hydraulic head of the basin, and pumped to an elevated holding tank for scavenger removal. Emergency drains provide for complete discharge of the settling basin to the river.

Alum is added to the suction side of the pump delivering water to the flocculation unit, utilizing pump action for initial mixing.

Following settling, water returns to the control house by gravity flow through 6" (15.24 cm) PVC pipe. The entire unit was constructed at the lowest elevation possible, with excavated earth graded to the maximum water level as protection against freezing, (Figure 10). Since no heat is provided in the unit, to protect against extreme winter weather common to Oakland, manual controls were provided to allow the flash mixer and flocculators to be operated during periods of shutdown to maintain water movement within the basin.

Figure 11 is a construction drawing prepared for the flocculation-sedimentation unit. Flocculators were designed and built specifically for the 9' x 15' (2.74 m x 4.57 m) flocculation chamber to facilitate the flow through design without directional change or use of overflow gutters.

Figure 10

Sedimentation Basin With Finished Grade Above
Water Line for Protection Against Freezing

Figure 12 is a schematic outline of the revised wastewater treatment and advanced water treatment flow. To facilitate comparison of sampling data between the original and revised unit, sampling designations remained unchanged with the addition of "X" to designate samples of water following sedimentation.

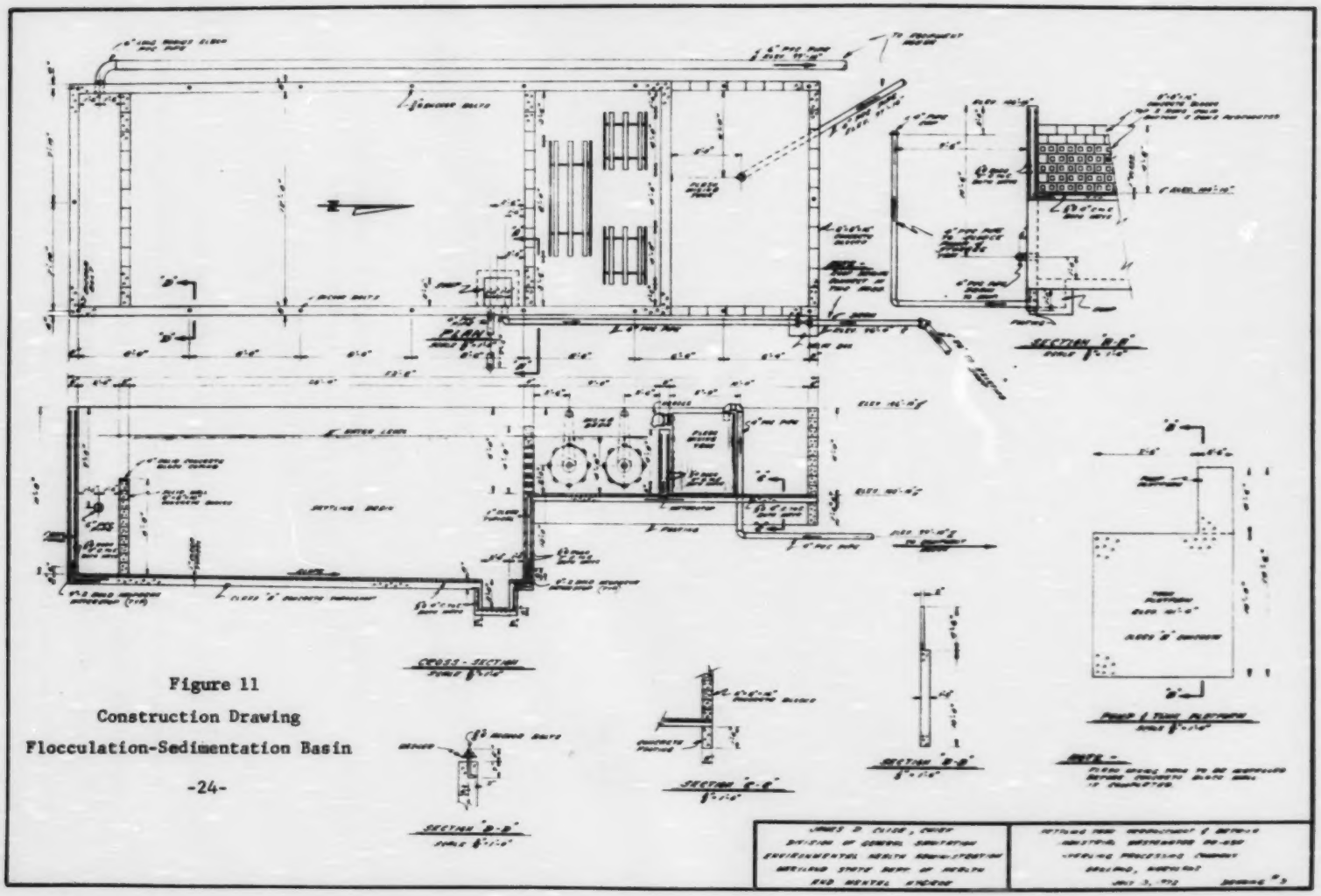


Figure 11

Construction Drawing

Flocculation-Sedimentation Basin

WASTEWATER TREATMENT AND WATER RECLAIMING FACILITIES

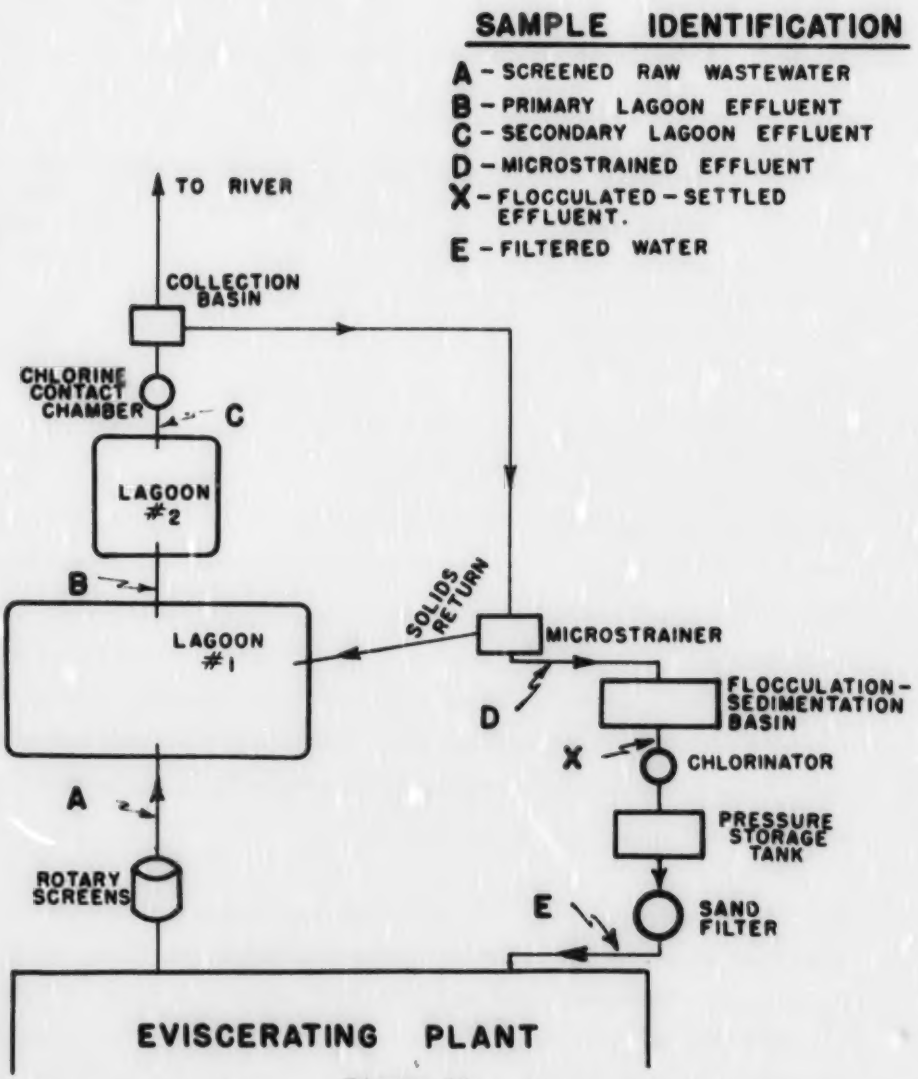


Figure 12

Revised Design

SECTION VI

OPERATION

Operations were conducted to provide advanced treatment of effluent from the existing two stage aerated wastewater treatment lagoon system. Effectiveness of the lagoon system in the treatment of poultry processing wastewater, as determined during the study, is indicated in Table 7.

Table 7. EFFECTIVENESS OF WASTEWATER LAGOON SYSTEM

mg/l

	Raw Wastewater			Primary Lagoon Effluent			Secondary Lagoon Effluent		
	N	$\bar{X}$	$\bar{O}$	N	$\bar{X}$	$\bar{O}$	N	$\bar{X}$	$\bar{O}$
BOD_5	148	543	229	79	251	176	210	39	40
COD	7	863	183	8	235	83	8	91	20
S.S.	119	831	464	67	392	342	214	117	100
Grease	47	403	239	10	95	90	78	18	17

N = Number of Samples $\bar{X}$ = Mean Value $\bar{O}$ = Standard Deviation

The operational phase was conducted in two segments. The first utilized facilities as originally designed consisting basically of a 30 micron microstrainer and diatomaceous filter. The second segment incorporated changes made in an effort to solve unanticipated treatment problems and utilized 70 micron screening, flocculation, sedimentation, and sand filtration.

Initially, secondary lagoon effluent was pumped directly from the overflow sump at the chlorine contact chamber as shown in Figure 13. Due to air entrapment and variation in overflow rate, a 3,000 gallon (11,360 liters) pit was inserted in the effluent line from the secondary lagoon to act as a reservoir for lagoon effluent and providing flooded suction for the self-priming pump. The pump discharges directly into the microstrainer drum.

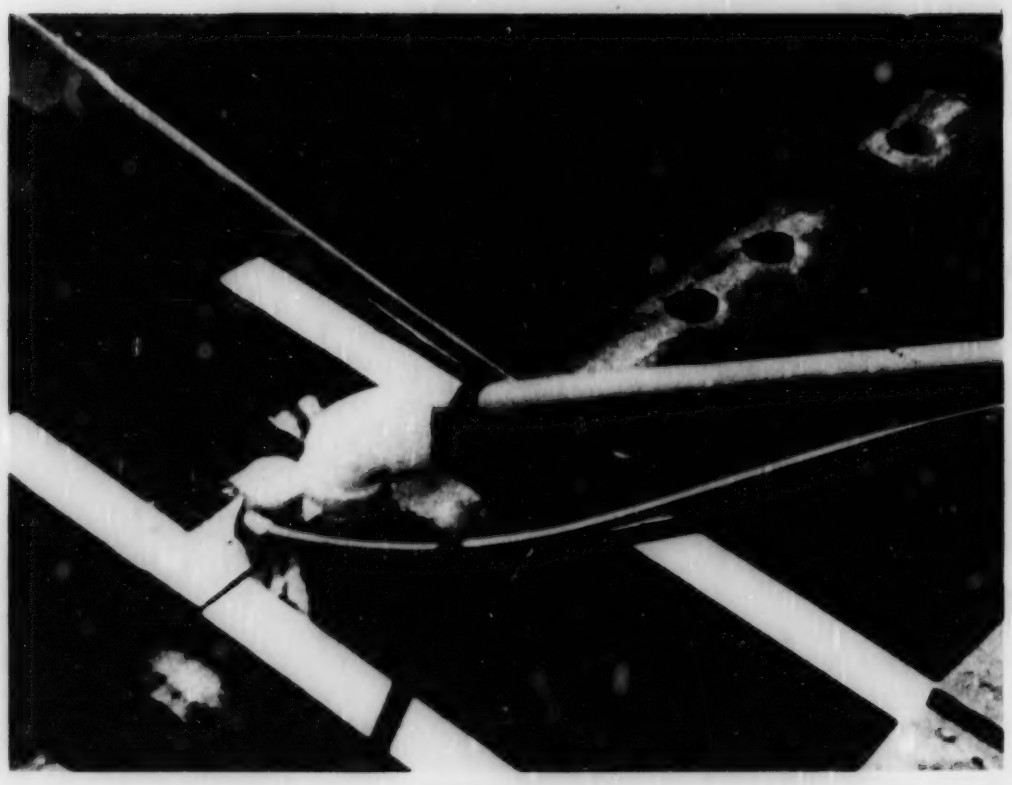
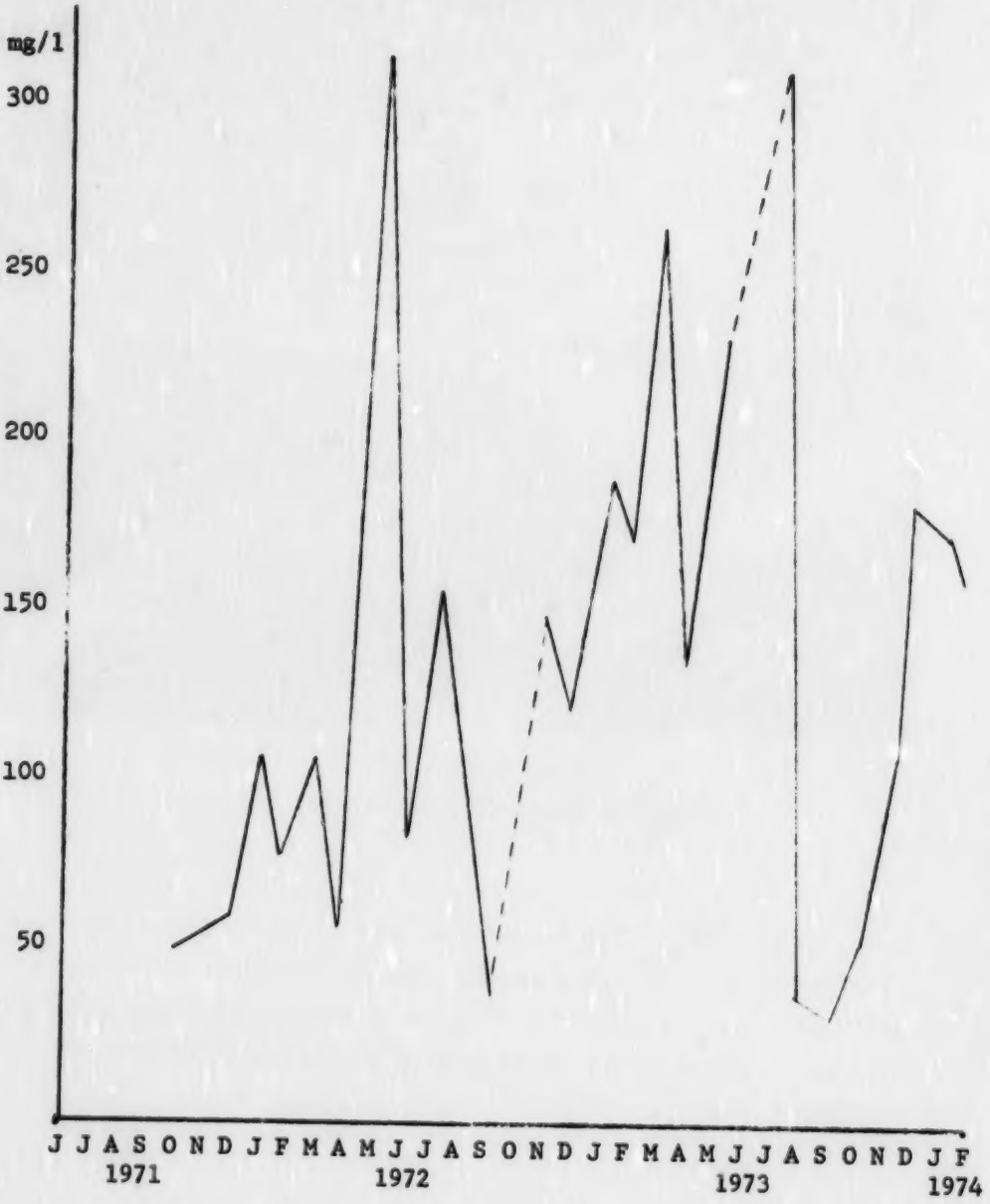


Figure 13
Overflow Sump, Chlorine Contact Chamber

Seasonal variations in suspended solids content of the lagoon effluent resulted in erratic flows through the 30 micron microstrainer. This difficulty was particularly noticeable during the algae growing season from May through August of each year as indicated in Figure 14.

Figure 14

Season Variation in Suspended Solids



During the winter months, when ice formation on the lagoon surfaces interferred with the operation of grease skimmers, particles of grease and tissue fibers were present in the wastewater lagoon effluent passing into the filter plant. Increased servicing of the skimmers, on a daily basis as opposed to the initial practice of weekly skimming, resulted in a reduction of grease content in the lagoon effluent. The effect of daily skimming, which was initiated in January, 1972, is reflected in Table 8.

Daily skimmer servicing resulted in the reduction of clogging of the microfilter screens. Maximum consistent flow, however, through the 30 micron screens never exceeded 167 gpm (10.5 1/s). Ultimately the 30 micron screens were replaced with 70 micron screens. These larger screen openings allowed a continuous flow of 300 gpm (19 1/s) through the microstrainers with the only appreciable decrease in effluent quality being the increase in suspended solids from a median value of 45 mg/1 to 96 mg/1. This increase was not significant with respect to the final water quality performance of the sand filter which tended to offset the effect of changing the screen size.

As indicated in Table 9, this suspended solids content is reduced in the settling basin to an average concentration of 38 mg/1. Sand filtration further reduced the suspended solids to an average of 5.1 mg/1.

Microstrainer screens were continuously backwashed by cold water sprays for removal of algae and other suspended particulate matter. Due to the presence of grease, it was necessary to provide a source of hot water for occasional removal of adhering matter.

Cold water for the microstrainer sprays was initially obtained from the discharge side of the high head pump transporting microstrained water to the filter. Due to the introduction of high levels of chlorine immediately before the take off point, difficulties were encountered from trichloramine fumes. Spray water take off was moved to the storage tank fed distribution system with a resulting reduction in chlorine fumes within the control house.

Table 8. GREASE CONTENT OF WASTEWATER LAGOON EFFLUENT

Weekly Servicing of Skimmers

mg/l

	N	$\bar{X}$	$\bar{0}$	Max.	Min.
Oct.	13	125	168.31	448	2
Nov.	12	64	92.76	285	3
Dec.	22	49	46.94	145	3
		Daily Servicing of Skimmers			
Jan.	7	14	6.64	23	8
Feb.	3	15	13.40	29	3
Mar.	13	19	10.25	37	4
April	17	11	8.98	24	0
May	7	22	21.00	53	2
June	5	15	8.13	27	8

N = Number of Samples $\bar{X}$ = Mean $\bar{0}$ = Standard Deviation

Table 9. EFFECTIVENESS OF EQUIPMENT

First Segment

mg/l

	Lagoon Effluent		Microstrainer Effluent - 30 m		Filtered Water (Diatomite)	
	N	M	N	M	N	M
BOD_5	179	25	106	8	129	6
COD	4	88	4	66	4	26
S.S.	164	109	144	45	171	9
Grease	83	19	101	5	101	3

Second Segment

mg/l

	Lagoon Effluent		Microstrainer Effluent - 70 m		Settled Water		Filtered Water (Sand)	
	N	M	N	M	N	M	N	M
BOD_5	36	24	25	10	25	6	40	0.5
COD	4	91	4	79	4	49	4	4.1
S.S.	37	149	25	96	25	38	32	5.1
Grease	18	13	8	6	5	4	16	3.6

N = Number M = Median Value

Chlorination

Laboratory studies utilizing "breakpoint" chlorination were undertaken in an effort to destroy grease. They indicated approximately 7.2 mg/l of chlorine was required to reduce 1 mg/l of grease to a stable compoind. At this point in the study grease content in the wastewater lagoon effluent was approximately 15.5 mg/l, which would exert a chlorine demand of 112 mg/l. Two gas chlorinators were used, one at the secondary lagoon contact chamber and one between the microstrainer and the diatomaceous earth filter, each operating at 80 lbs/day (36 kg/day) for a total capacity of 160 lbs/day (75 kg/day). This rate approximated 45 mg/l of chlorine, compated to the 112 mg/l required by the average concentration of grease, so "breakpoint" was not consistently reached.

The use of highly chlorinated water in the microstrainer sprays resulted in release of excessive chloramine fumes within the control house. The problem was reduced by supplying microstrainer sprays with water from the pressure storage tank. "Breakpoint" was more consistently reached following storage in the tank.

Attempts to satisfy chlorine demand resulted in formation of an opalescence in the filtered water. At times, when opalescence was not present in the diatomite filter effluent, it was noticed in the filtered reclaimed water following storage in the pressure storage tank. This opalescence was assumed to be the result of colloidal solids which coagulated at pH ranges below 4.6 resulting from excessive chlorine content, indicating the probability of colloidal protein being present in the wastewater lagoon effluent. Efforts to verify the presence of protein through the use of available laboratory capabilities, including the use of an infrared spectrophotometer, were inconclusive.

The presence of protein was supported, however, by evaluation of the nitrate nitrogen present. Protein from animal sources normally contains approximately 16% nitrogen. Therefore the concentration of protein

present can be 6.25 times the concentration of nitrogen. Nitrate nitrogen present in the wastewater lagoon effluent averaged 7.0 mg/l throughout the study. Normal nitrate nitrogen concentration of Sterling's water supply, based on routine analyses conducted during the study, was 2.3 mg/l. Subtracting this value from the nitrate nitrogen present in lagoon effluent and applying the factor of 6.25 indicates a possible protein content of 29.4 mg/l:

$$(7.0 - 2.3)\ mg/l \times 6.25 = 29.4\ mg/l\ protein$$

Flocculation and Sedimentation

To eliminate problems of colloidal content, grease, and excessive solids, additional facilities were designed and constructed to provide for flocculation and sedimentation of wastewater effluent following microstraining and prior to filtration. The construction was completed and the unit placed in operation in the early spring of 1973, and was used during the remaining months of the project.

Laboratory examinations and jar tests were used to determine most efficient and effective coagulation materials. Floc formation was attained through addition of 5 grains per gallon (86 mg/l) of alum followed by the addition of an equal amount of lime.

Optimum levels of coagulants for formation of floc, as determined by daily jar tests, remained relatively constant throughout the study. Jar tests were conducted using 1 liter samples of microstrainer effluent and mechanical stirring. Initial "flash" mixing was accomplished at 100 rpm for five minutes followed by flocculation at 50 rpm for fifteen minutes. The subsequent subsistence period was 30 minutes.

Effectiveness of flocculation and sedimentation in the removal of suspended solids was approximately 60% (Table 9) with the use of alum and lime as coagulants. Preliminary indications from jar testing were that more rapid floc formations could be obtained through addition of polymer aids. Termination of the project, however, prevented adequate evaluation of such additives.

Diatomaceous Earth Filter

Solids carry-over onto the diatomite filter during early stages of operation, in excess of those anticipated in the design state of the project, resulted in extreme reduction of volume through the unit and excessive backwashing. Solids, originally identified as grease but later found to be mixed with protein, passed through the micro-strainer so were apparently in an emulsified or colloidal state.

At the beginning of the project, two grades of diatomaceous earth were tested as filter media. These were Johns Manville Hyflow Super Cel, which is a medium grade of diatomaceous earth, and Johns Manville 545 which is the next coarser grade. The 545 consistently produced filter runs of twice the length obtained with the finer earth and was used throughout the remainder of the first phase of the study. Table 10 indicates the difficulties encountered in the use of diatomaceous earth as a filter media for a typical three week period. These filter runs were made using 545 media with an application of 1 mg/l body feed.

Effectiveness of the use of body feed in extending the length of filter runs was evaluated. An application of 1 mg/l of 545 diatomaceous earth as a body feed, as indicated in Table 11, produced longer filter runs when based on 90 psi (621 kN/m^2) as the final inlet pressure. This increase in filter runs was minimal, however, and was discontinued midway through the study period.

Table 10. DIATOMACEOUS EARTH FILTER RUNS

N	$\bar{X}$	$\bar{O}$	Max.	Min.
		Volume - gallons		
31	25,373	18,783	71,700	3,600
		Time - minutes		
31	137	92.8	332	19
		Rate - gpm		
31	185	16.1	202	37
		Head Loss - lbs/min		
31	0.53	0.45	1.77	0.05

Table 11. EFFECT OF BODY FEED IN EXTENDING DIATOMACEOUS FILTER RUNS

	Total Gallons	Length of Run Minutes	Gallons Per Minute	Gallons/Ft^2 Minute	Accumulated Head Loss psi
		With Body Feed - 1 mg/l			
Number Runs	17				
Average Run	29,518	156	194	0.64	28
Maximum Run	66,300	332	200	0.66	28
Minimum Run	3,600	19	189	0.63	14
		Without Body Feed			
Number Runs	14				
Average Run	19,840	113	173	0.57	33
Maximum Run	34,744	202	172	0.57	29
Minimum Run	6,475	37	175	0.58	33

The diatomaceous earth filter proved to be totally inadequate for use with water of the quality being applied. In no instance was the design volume of 300 gpm (19 liters/s) attained.

Sand filter

During the second segment of the study the diatomaceous earth filter was bypassed and one of the sand filters in the Sterling water treatment unit was used.

Each of the two 15' diameter sand filters in the Sterling water treatment unit has sufficient capacity to filter the total demand flow for the poultry plant. The piping to one filter was altered to allow it to be used as a standby for the Sterling water treatment plant and also as the final filter for the project's advanced water treatment unit. The sand filter proved capable of filtering the applied water at a continuous rate of 300 gpm (19 liters/s) with weekly backwash.

Piping arrangement allowed water from the sedimentation basin clear well to be pumped to the Sterling sand filter. The filtered water could then be returned to the primary wastewater lagoon, bypassed directly to the river, or discharged into the raw water basin of Sterling's water treatment unit. This arrangement provided the opportunity to compare effectiveness of sand filtration to diatomaceous earth filtration of the reclaimed water.

During this segment of the study, one diatomaceous earth filter run was made each day for a period of 15 days to allow comparison of its effectiveness with sand filtration. Results of this comparison are shown in Table 12.

Table 12. COMPARISON OF EFFECTIVENESS OF DIATOMACEOUS EARTH AND SAND FILTRATION

mg/l

	Diatomaceous Earth		Sand	
	N	M	N	M
BOD_5	15	0	15	0.5
COD	3	3.8	3	4.1
S.S.	15	2.4	15	5.1
Grease	15	0	15	3.6
Volume (gpm)	15	167	15	300
Rate $gal/ft^2/min$		0.84		1.7

Reuse

The Sterling plant was closed for a period of six weeks due to a labor strike. This provided an opportunity to study problems and effects relating to the use of reclaimed water to augment the Sterling water supply.

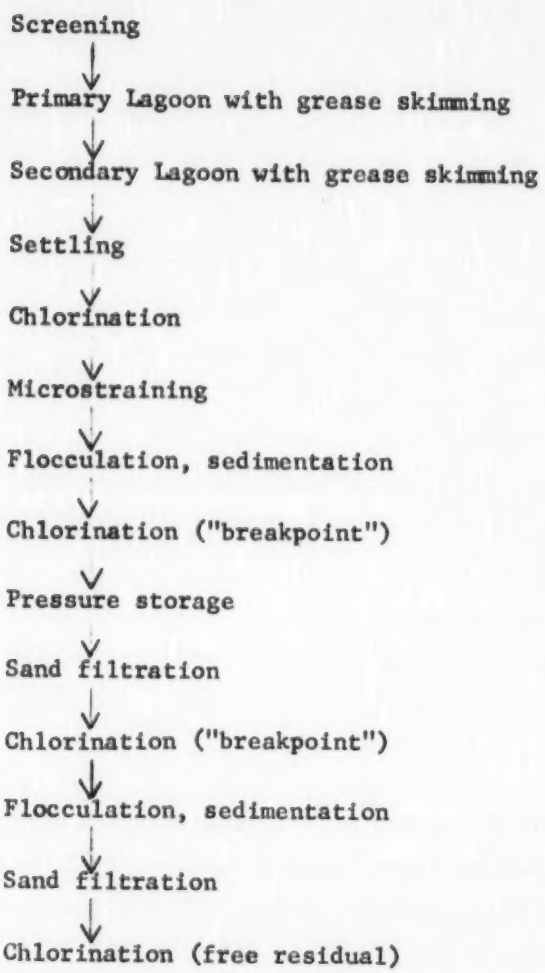
During this period, the Sterling plant's water treatment unit was operated at capacity with the total volume discharged through the plant's drainage system into the primary wastewater lagoon. Lagoon effluent was treated in the advanced treatment unit utilizing sand filtration. Reclaimed water was introduced into the Sterling plant supply at the rate of 100 gpm (6.3 l/sec), 200 gpm (12.6 l/sec), and ultimately 300 gpm (18.9 l/sec).

To resolve pressure variation difficulties inherent in the interconnection of two pressure systems, and further, to provide maximum treatment of reclaimed water, water from the advanced treatment unit was introduced into the raw water basin of the Sterling water treatment unit, and introduced into the poultry plant's distribution system through Sterling's pumping arrangement. Continuous monitoring of the

integrated supply demonstrated the ability to maintain a free chlorine residual throughout the system and the maintenance of a turbidity level of less than 2 (JTU). The treatment facilities utilized during this operation are shown in Figure 15.

Figure 15

Wastewater Treatment and Advanced
Water Treatment Route of Flow



Four points of chlorination are contained in the complete treatment processes:

1. Chlorination of secondary lagoon effluent. Rate of chlorination at this point is determined by level of disinfection necessary for the control of coliform in effluent discharged to the river. A minimum of 30 minutes' contact time is provided with the objective of 1 mg/1 of free residual chlorine in discharged effluent. At the beginning of the study it was discovered that short circuiting of the contact chamber often resulted in the presence of free chlorine in discharged effluent without effective disinfection. The chlorine difuser line was lengthened to extend the entire length of the chlorine contact chamber. Normal rate of application in the chlorine contact chamber for bacteriological control has been established at 20 lbs/day.

2. Chlorination of settling basin effluent. Chlorine is added on the suction side of the pump which delivers settled water to the pressure storage tank prior to filtration. During the first operational segment of the study, water was filtered prior to discharge into the pressure tank. During the second segment, water was pumped into the pressure storage tank prior to delivery to the sand filter. This procedure provides for an additional 30 minute period of chlorine contact.

   Chlorine dosage at this point is determined by chlorine demand. Normal dosage rate is 20 lbs/day with the objective being the reaching of "breakpoint."

3. Pre-chlorination, Sterling water treatment raw water basin. Rate of chlorination is 5 lbs/day to control biological growth within the unit and to satisfy chlorine demand of raw water. Objective is to reach "breakpoint" and to carry a chlorine residual onto the sand filter surface.

4. Chlorination of filter effluent. Final chlorination is provided at the rate of 5 lbs/day, with chlorine introduced into water service main entering the processing plant. The objective is to assure a chlorine residual throughout the poultry plant distribution system.

SECTION VII

RECLAIMED WATER QUALITY

Sampling and Analytical Procedures

The study provided for chemical and physical examination of samples collected from each of five sampling points throughout the system. Samples were collected routinely of raw wastewater, primary and secondary lagoon effluent, microstrainer effluent, and filtered water. During the second operational segment, samples of settled water and comparison samples of filtered water from the diatomaceous earth and sand filters were also examined.

Samples of raw wastes and wastewater secondary lagoon effluent were composited over 24 hours and collected once each day. Grab samples were collected of the primary lagoon effluent and from each point in the advanced water treatment unit. Sampling procedures allowed for continuous evaluation of effectiveness of each phase of the wastewater lagoon treatment and advanced water treatment processes.

Following filtration, finished water from the advanced water treatment unit was routinely subjected to both wastewater and drinking water examinations.

Quality Control Procedures

Routine chemical and bacteriological examinations were conducted in the Cumberland, Maryland, branch laboratory which operates under supervision of the Laboratories and Research Administration of the Maryland State Department of Health and Mental Hygiene. Specialized chemical, virology, and chromatograph examinations were conducted in the Administration's central laboratory in Baltimore, Maryland.

All examinations were made in accordance with the procedures established in the following:

The Standard Methods for the Examination of Water and Wastewater, 13th Edition, 1971. Published by American Public Health Association, and Water Pollution Control Association.

EPA Methods for Chemical Analyses of Water and Wastes, 1971. Published by Environmental Protection Agency.

Handbook for Analytical Quality Control in Water and Wastewater Laboratories, 1972. Published by Environmental Protection Agency.

Pesticide Analytical Manual, Food and Drug Administration.

Polyelectrolyte Technique for Virus Detection as developed by Dr. Joseph L. Melnick (Baylor University).

Chemical - Physical Evaluation

Results of chemical and physical examinations of reclaimed water throughout both segments of the operational phase of the study are shown in Table 13. With the exception of turbidity, study facilities proved capable of consistently reaching standards established for drinking water for each characteristic studied. Facilities used during the second segment of the study's operational phase proved capable of producing a finished water with turbidities ranging from 1 to 3 units.

As indicated previously, the limited period of study following completion of the settling basin did not allow thorough evaluation of advantages of coagulant aids. Increased efficiency of coagulation should result in more consistent turbidity control. Although chloride content of the finished water was consistently below the allowable limit of 500 mg/l, continuous recycling of wastewater could result in chloride's buildup exceeding satisfactory levels.

Table 13. CHEMICAL-PHYSICAL QUALITY OF RECLAIMED WATER

mg/l

	Drinking Water Standard-1962	N	$\bar{X}$	$\bar{0}$
Turbidity (JTU)	5	54	3.5	1
Color	15	90	5	7
Pesticides		16	0	
pH		207	6.6	1.4
Alkalinity		101	104	57
Hardness		22	131	24
Dissolved Solids	500	158	335	129
Chloride	250	162	117	53
Cyanide	0.2	8	0	
Fluoride	1	23	0.21	0.13
Nitrate (NO_3)	45	89	31	8
Phosphate		47	10	2
Sulfate	250	23	13	5
Aluminum		17	0.03	0.04
Arsenic	0.05	26	0.01	0.01
Cadmium	0.01	8	<0.01	0
Calcium		26	46	12
Chromium^6	0.05	8	<0.01	0
Copper	1.0	26	0.06	0.01
Iron	0.3	27	0.27	0.19
Lead	0.05	8	0.01	0.01
Manganese	0.05	10	0.02	0.02
Mercury	0.005	8	0.003	0.003
Potassium		20	10.7	9.5
Selenium	0.01	8	<0.01	0
Silver	0.05	8	<0.01	0
Sodium	270	19	21	15

N = Number of Samples $\bar{X}$ = Mean Value $\bar{0}$ = Standard Deviation

The effectiveness of various stages of treatment on water clarity is demonstrated by Figure 16.

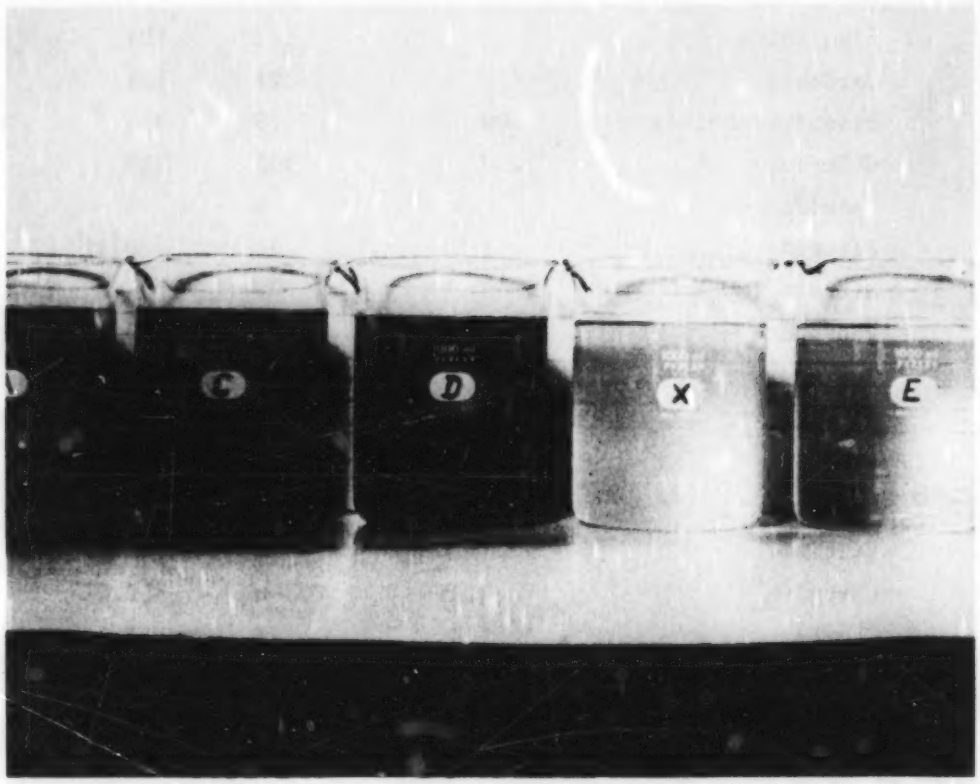


Figure 16

Water Clarity Comparison

A. Raw Wastewater
C. Wastewater Treatment Lagoon Effluent
D. Microstrainer Effluent
X. Flocculated-settled Water
E. Filtered Water (Sand Filter)

Bacteriological Evaluation

Bacteriological samples were collected routinely from the overflow line from the wastewater lagoon chlorine contact chamber to determine the reliability of chlorination of lagoon effluent. A chlorine feed rate of 20 lbs/day (8 mg/1) was determined adequate to assure the discharge of effluent containing fewer than 240 fecal coliform/100 ml. At a chlorination rate of 20 lbs/day (8 mg/1), 90% of the samples collected over a two year period contained < 3 coliform/100 ml.

During the study period, 352 bacteriological samples of filtered water from the advanced water treatment system were collected and examined for coliform, fecal strep, and total plate counts. A chlorine application rate of 20 lbs/day (8 mg/1) prior to filtering resulted in consistent bacteriological counts of < 3 coliform/100 ml; < 1 fecal strep/100 ml; and a standard plate count of < 100/ml. The chlorination rate of 60 - 80 lbs/day, necessary to reach "breakpoint" during the 66 minute retention period in the pressure storage tank prior to filtering, provides additional assurance of bacteriological safety of the water.

Virus Control

Examination procedures to assure the total absence of viable virus organisms in water are not presently available. U. S. P. H. S. Drinking Water Standards - 1962, indicate the inactivation of enteric viruses in water requires a minimum free chlorine residual of 0.3 mg/1 for 30 minutes, or 9 mg/1 of combined residual for 3 minutes. As indicated in Figure 15, chlorine was added in the wastewater lagoon contact chamber. Chlorination at this point was in sufficient amount to provide a combined residual following 30 minutes' retention. Additional chlorination, at the rate required to reach "breakpoint" during a minimum of 60 minutes' retention, was provided prior to filtration.

Maryland's Laboratories and Research Administration has the capability of identifying human enteric virus organisms in water. During the study nine five gallon (18.9 liter) samples were composited at random from filtered reclaimed water and examined for human enteric virus organisms. All samples were negative.

Continuous automatic monitoring and recording of free chlorine residual was provided.

SECTION VIII

FINANCIAL CONSIDERATIONS

Initial cost of the two wastewater treatment units was $84,000, excluding land value. Construction cost of the advanced water treatment unit, including control house, covered sedimentation basin, 1000 feet (305 m) of pipe line and equipment, was $89,998.50, resulting in a combined construction cost of $173,998.50.

Annual costs are summarized in Table 14. To arrive at the annual cost of Sterling's wastewater treatment unit, depreciation is considered at 10%. Annual costs of the advanced water treatment unit, due to the variety of equipment, include individual depreciation rates as determined from the Internal Revenue Service depreciation schedule. Interest on investment is charged at an annual average rate of 8% for both units. One full time operator's salary is shared between the two units.

Annual cost of the wastewater treatment unit has been determined to be $22,658.75. Annual cost of the advanced water treatment unit is $19,976.77, for a combined annual cost of $42,135.52. This is equal to a total wastewater treatment and water reclaiming cost of $1.01/1000 lbs LWK ($2.22/1000 kg LWK).

Table 14. ANNUAL AND CAPITAL COSTS

Wastewater Lagoon System			
Initial Investment	$84,000.00		
Average Annual Interest at 8%			$3,360.00
Depreciation (10% annual)			8,400.00
Chlorine	10,950 lbs @ $13.50 cwt		1,478.25
Electricity	378,500 kWh @ $0.013		4,920.50
Plant Operator	1/2 time @ $9,000.00		4,500.00
		Annual Cost	$22,658.75
Advanced Water Treatment System			
Initial Investment	$89,998.50		
Average Annual Interest at 8%			$3,599.00
Depreciation (I.R.S. Schedule)			5,187.52
Materials			
Chlorine	3,750 lbs @ $13.50 cwt	$506.25	
Lime	50,000 lbs @ $1.90 cwt	950.00	
Alum	50,000 lbs @ $5.00 cwt	2,500.00	
		$3,956.25	3,956.25
Electricity	172,000 kWh @ $0.013		2,236.00
Plant Operator	1/2 time @ $9,000.00		4,500.00
		Annual Cost	$19,476.77
Total Annual Cost			$42,135.52
Total Capital Cost	$173,998.50		

For purposes of comparison, capital costs and annual costs were computed on the basis of average daily volumes. On the basis of annual costs, an average flow of 0.288 mgd, and 250 working days/year, the cost of treatment in the wastewater lagoon unit was determined to be $0.31/1000 gal with advanced water treatment cost determined to be $0.27/1000 gal, for a total treatment cost of $0.58/1000 gal. Capital costs for the wastewater lagoons and advanced water treatment system were $2.91/gpd capacity and $3.12/gpd capacity, respectively.

SECTION IX

DESIGN FACTORS

Influent pump

self priming sewage pump - 10 hp (7.457 kw)

300 gpm (19 l/s)

40 feet total head (12,192 kgs/m^2)

Microstrainer

70 micron filter screen

108 sq ft screen area (10 m^2)

300 gpm (19 l/s)

Chemical feeder

slurry type

dual head

variable

Low head pump

flooded suction - 2 hp (1.49 kw)

300 gpm (19 l/s)

10 feet total head (3048 kg/m^2)

Mixing tank

4' 6" x 5' 8" (1.37 m x 1.73 m)

600 gal (2271 l)

2 min flash mixing

Flash mixer

gear driven - 1/3 hp (.248 kw)

10" propeller (25.4 cm)

350 rpm

Chemical feeder

volumetric type

1/12 hp (.062kw)

12 lbs/hr (lime) max. (5.44 kg/hr)

Flocculation basin

15' x 9' x 4' (4.6 m x 1.2 m)

4050 gal capacity (15,330 l)

13 min flocculation time

Flocculators

horizontal type

2 - 10' (3.05 m) units - wooden slot

1/2 hp - 2'/sec (.37 kw - 0.6 m/s)

Sedimentation basin

15' x 30' x 10' deep (4.6 m x 9.2 m x 3.05 m)

2 hr retention

overflow rate 950 gal/day/ft^2 (38,700 l/day/m^2)

Pump

portable, diaphragm type - sludge pump

1/2 hp (.37 kw)

Tank - sludge storage

elevated

10' diameter x 5' deep (3.05 m x 1.52 m)

cone bottom

Chlorinator

cylinder mounted

100 lb/day max (45.36 kg/day)

Platform scale

single beam

100 lb graduations (45.36 kg)

Pump

flooded suction - 20 hp (14.9 kw)

300 gpm (19 1/s)

180 feet total head (55,000 kgs/m^2)

Filter

diatomaceous earth

2 gal/min/ft^2 (1.36 1/s/m^2)

300 gpm capacity (19 1/s)

Chlorine monitor

free chlorine residual analyzer

0 - 3 mg/l

30 day continuous recorder chart

Tank

pressure storage

10' diameter x 54' (3.05 m x 16.5 m)

20,000 gal capacity (76,000 1)

Air compressor

1/2 hp (.37 kw)

3.8 cu ft/min (0.11 cu m/min)

175 psi (1,207 kN/m^2)